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Yield and Water Use Efficiency of Grain Sorghum in a Limited Irrigation–Dryland Farming System[1]

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ABSTRACT

A Limited Irrigation-Dryland (LID) farming system for the conjunctive use of rainfall and limited irrigation of graded furrows was developed and field tested. The unique feature of the LID system is that it actually adjusts, during the crop growing season, the amount of land irrigated since more land can be irrigated during above-average rainfall years with a limited amount of irrigation water than during below-average years. The design used a limited water supply to irrigate a larger area than could be conventionally irrigated. A graded furrow field, 600 m long on a 0.3 to 0.4% slope was divided into three water management sections. The upper half of the field was managed as "fully irrigated." The next one-fourth was managed as a "tailwater runoff" section that utilized furrow runoff from the fully irrigated section. The lower one-fourth was managed as a "dryland" section capable of utilizing runoff from either rainfall or irrigation on the wetter sections. The system was field tested for 3 years with grain sorghum (*Sorghum bicolor* (L.) Moench) on a Pullman clay loam (fine, mixed, thermic family of Torretic Paleustolls). Seasonal rainfall values were 224 mm in 1979, 103 mm in 1980, and 424 mm in 1981 as compared to the average of about 250 mm. The LID system was successful in increasing the utilization efficiency of irrigation water. Irrigation water added to a field can be transpired, evaporated, percolated, lost as runoff, or left stored in the soil after harvest. The LID system tended to reduce all losses other than transpiration. When 125 mm or 185 mm of irrigation water were added with the LID system, the evapotranspiration by grain sorghum was increased by an almost equal amount. This increased grain yield an average of 154 kg/ha for each 10 mm added irrigation, compared to 92 kg/ha for each 10 mm under conventional irrigation practices.

Additional index words: **Evapotranspiration, Runoff, Plant density, Furrow dams.**

CROP production in the Great Plains is generally limited by lack of water. Irrigation, with ground water from the High Plains Aquifer, has been widely used to overcome this limitation. Irrigation in the Great Plains has increased from about 3.7 million ha in 1954 to more than 8.5 million ha in 1978, and accounts for over 40% of all the irrigated cropland in the USA. The High Plains Aquifer, the primary source of irrigation water for the Great Plains, is being rapidly depleted in some areas, particularly in the Southern High Plains. The High Plains Aquifer underlies 45 million ha and contains an estimated 27×10^{12} m^3 of water (Weeks and Gutentag, 1981). If this water was evenly distributed, there would be about 58 m water under the land. The water is not, however, evenly distributed and the land-to-water ratio is considerably greater in the Southern High Plains. Texas, Oklahoma, and New Mexico contain 30% of the aquifer area but only about 15% of the water volume. Nebraska contains 36% of the aquifer area and 64% of the volume.

Irrigation from ground water in the Southern High Plains is expected to decrease rapidly in future years because of the declining aquifer level. The rate of decrease could even be greater if energy supplies for pumping become limited or too costly. A recent study (U.S. Dep. of Commerce, 1982) projected that irrigation water use from the aquifer by the states of Texas, Oklahoma, and New Mexico in the year 2020 will be 570×10^6 m^3, compared to 1.22×10^9 m^3 used in 1977. The same study, however, projected that the number of hectares irrigated would only decrease by 18%, which indicated that the constraints of supply and costs will lead to more efficient utilization of irrigation water.

Stewart et al. (1981) developed a Limited Irrigation-Dryland (LID) system that uses a limited water supply to irrigate a larger area than could be fully irrigated and thus reduces the area in nonirrigated crops. The LID system has been field tested for three seasons in the Southern High Plains. The objective of this research was to evaluate the effectiveness of the system. Although the design and results of a specific system are reported, the

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primary emphasis is on the concept of the system. Specific details will need to be modified for different soils, crops, rainfall, and irrigation water supplies.

MATERIALS AND METHODS

The LID concept and the background information that led to its development have been presented by Stewart et al. (1981). The objective of the LID concept is to maximize the conjunctive use of growing season rainfall with a limited supply of irrigation water. The unique feature of the LID system is the flexible adjustment during the crop growing season of the amount of land irrigated, allowing more land to be irrigated during above average rainfall years than during dry years. The concept is illustrated in Fig. 1. A graded furrow field, 600 m long on 0.3 to 0.4% slope was divided into three water management sections. The upper half of the field was managed as "fully irrigated." The next one-fourth was managed as a "tailwater runoff" section that utilized furrow runoff from the fully irrigated section. Finally, the lower one-fourth was managed as a "dryland" section capable of receiving and utilizing any runoff resulting from either irrigation or rainfall on the wetter, fully irrigated and tailwater runoff sections. Plant densities were reduced down the field to alleviate stress because irrigation water was decreased as the length of the field increased. Furrow dams (Clark and Hudspeth, 1976) were placed about every 4 m throughout the length of the field. Alternate 760-mm spaced furrows were irrigated, and the dams in the irrigated furrows were notched to ensure that irrigation water moved over the dams and down the furrow, rather than across the bed. The dams were washed out by the irrigation water to the distance that the water advanced down the field. The remaining furrow dams on the lower part of the field, and the dams in the nonirrigated furrows for the entire length of the field, prevented rainfall runoff. A predetermined amount of irrigation water was applied at regular time intervals. The extent to which the entire field was irrigated depended on the rainfall received; the wetter the year, the greater the advance of a fixed application down the field. The objective was to prevent or minimize any water from rainfall or irrigation from leaving the field.

Irrigation water was applied through gated pipe, and flow rates to individual furrows were calibrated by using a measuring bucket and stopwatch. Tailwater runoff from four furrows was measured with individually calibrated 30-cm H-flumes equipped with water stage recorders. Two flumes were installed for each plot and a small dam was placed in front of one so that low flows would be measured by one flume, but both would be available when large runoff events occurred.

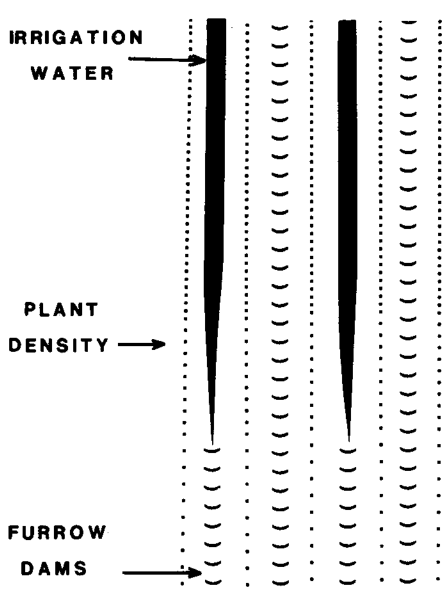

Fig. 1. Schematic drawing of the Limited Irrigation-Dryland (LID) system.

The study was carried out on an 8-ha field that was fallowed in 1978 prior to beginning the study in May 1979. Following harvest each year of the study, the field was tilled with a disk and later plowed with a moldboard plow. The field was bedded with a disk bedder in early spring and every furrow was irrigated to wet the field uniformly. The soil was Pullman clay loam, the predominant soil in the Southern High Plains and a member of the fine, mixed, thermic family of the Torretic Paleustolls.

Experimental Treatments

Treatments were placed on a 575-m long field site to test variations of the proposed system and to compare the system with dryland and fully irrigated treatments. 'Northrup King 2778', a medium-late maturing grain sorghum hybrid (*Sorghum bicolor* (L.) Moench), was used for all treatments in 1979. In 1980 and 1981, 'DeKalb DK57' was used. Plots were seeded on 25 May 1979, 2 June 1980, and 28 May 1981. Propazine [2-chloro-4,6-bis (isopropylamino)-*s*-triazine] at the rate of 3 kg/ha, was applied preplant for weed control on 2 Apr. 1979 and incorporated with a rolling cultivator. In 1980 and 1981, atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] was applied at the time of seeding for weed control. Other characteristics of the treatments were as follows:

Dryland. Grain sorghum was seeded at about 1.5 kg/ha in single rows on top of the beds to achieve a plant density of about 40,000 plants/ha.

Dryland, Dammed. Grain sorghum was seeded identically to dryland treatment, except furrow dams were placed in every furrow at about 4-m intervals. Flumes for measuring runoff were not installed because furrow dams prevented runoff.

Fully Irrigated. Grain sorghum was seeded at 6 kg/ha to achieve about 160,000 plants/ha. Anhydrous ammonia at the rate of 180 kg N/ha was uniformly applied about 6 weeks prior to seeding. The treatment was irrigated five times at 14-day intervals with approximately 100 mm water each time. Water was applied to each furrow for 24 h. In 1979, 38 L/min were applied to each furrow but in 1980 and 1981, the wheel-track furrows (one of each two furrows) received only 26 L/min. Also, in 1981, only four irrigations were applied because of late season high precipitation amounts. The entire length (575 m) of the plot was irrigated, and we anticipated that about 25% of the applied water would be lost from the field as tailwater. This amount is somewhat typical of fully irrigated fields and is required to allow time for wetting the lower part of the field. Flumes, as discussed above, were installed to measure runoff from rainfall and irrigation.

LID-250 mm. The Limited Irrigation-Dryland (LID) treatments had the upper 300 m of field length seeded at 6 kg/ha, the next 150 m at 3 kg/ha, and the lower 125 m at 1.5 kg/ha. The seeding rate changes were made by stopping the planter and changing the sprocket that drove the chain running to the seed metering equipment. However, Stewart (1983) has described an automated seeding rate selector that allows seeding rate changes without stopping the planting operation. Anhydrous ammonia was applied at the rate of 135 kg N/ha to the upper 300 m and at 65 kg N/ha to the remaining 275 m. All furrows were dammed at 4-m intervals after seeding, but the dams in furrows to be irrigated were cupped to insure irrigation water would overflow the dams and move down the furrow. In 1979, each furrow was irrigated, but only alternate furrows were irrigated in 1980 and 1981. The dams in the nonirrigated furrows were left as high as the beds. Plots were irrigated every 14 days in 50-mm applications, based on the total area within the plot. The water, however, was not uniformly distributed over the whole area. It was applied at the upper end of the furrow and the distance that it advanced down the field depended pri-

Table 1. Seasonal rainfall, applied irrigation, runoff, and net seasonal soil water changes for various water management treatments.

		Seasonal rainfall†				Applied irrigation				Runoff				Soil water change‡			
Treatment	Area	1979	1980	1981	Avg.	1979	1980	1981	Avg.	1979	1980	1981	Avg.	1979	1980	1981	Avg.
		mm															
Dryland	S	224	103	424	250	0	0	0	0	13	0	76	30	−155	−122	+40	−79
	N	224	103	424	250	0	0	0	0	13	0	76	30	−149	−122	+65	−69
					250				0				30				−74
Dryland, dammed	S	224	103	424	250	0	0	0	0	0	0	22	7	−152	−152	+105	−66
	N	224	103	424	250	0	0	0	0	0	0	22	7	−151	−132	+99	−61
					250				0				7				−64
Fully irrigated	S	224	103	424	250	583	504	422	503	252	123	223	199	−98	−73	+61	−37
	N	224	103	424	250	602	530	451	528	213	97	152	154	−118	0	+48	−23
					250				516				177				−30
LID-250 mm	S	224	103	424	250	245	253	202	233	0	0	34	11	−123	−84	+82	−42
	N	224	103	424	250	247	251	202	233	0	0	17	6	−130	−94	+83	−47
					250				233				9				−45
LID-185 mm (5)	S	224	103	424	250	185	186	150	174	0	0	17	6	−100	−129	+91	−46
	N	224	103	424	250	185	187	150	174	0	0	8	4	−139	−91	+94	−45
					250				174				5				−46
LID-185 mm (3)	S	–	103	424	–	–	186	186	–	–	0	41	14	–	−108	+84	–
	N	–	103	424	–	–	185	186	–	–	0	15	5	–	−115	+117	–
													10				
LID-125	S	224	103	424	250	123	130	103	119	0	0	38	13	−111	−152	+105	−53
	N	224	103	424	250	123	130	103	119	0	0	24	8	−130	−115	+91	−51
					250				119				11				−52

† Rainfall between seeding and harvest dates.
‡ Change in soil water to 180 cm between seeding and harvest dates.

marily on the soil water content and associated soil profile shrinkage volume. The dams in the irrigated furrows were removed by the flowing water to the distance that the water advanced and were not rebuilt. A total of 250 mm of irrigation water was applied both in 1979 and 1980, but only 200 mm were applied in 1981 because rainfall prevented the need for the last irrigation during grain filling. In 1979, all furrows were irrigated, 30 L/min were applied to each furrow for 12 h. In 1980 and 1981, 60 L/min were applied to alternate furrows for 12 h. Flumes were installed to measure runoff from rainfall and irrigation.

LID-185 mm(5). This treatment was seeded and fertilized in the same manner as the LID-250 mm. Only 37 mm of irrigation water were applied each time, and water was applied in alternate furrows in all years. Water was applied at 14-day intervals to the irrigated furrows at the rate of 45 L/min for 12 h. Five irrigations were applied for a total of 185 mm for the season. However, in 1981, only four irrigations were applied because of late season rainfall. Flumes were installed for measuring runoff.

LID-185 mm(3). This treatment was added in 1980 and was therefore present in the study for only 2 years. The treatment was identical to the LID-185 mm(5) except the irrigation water was added in three applications at 21-day intervals instead of five applications at 14-day intervals. The water was applied to alternate furrows at the rate of 40 L/min for 24 h.

LID-125 mm. A total of 125 mm of irrigation water was applied on this treatment. In 1979, two rows were seeded, as described for the LID-250 mm treatment, and alternated with one row that was not seeded. All furrows were dammed at 4-m intervals, but only the dams in the furrow between the planted rows were cupped. This furrow was irrigated at 14-day intervals by applying 45 L/min of water for 12 h, thus applying 25 mm/ha, and a total of 125 mm for the season. In 1980 and 1981, the skip-row part of the treatment was deleted and 125 mm of irrigation water were applied in three applications at 21-day intervals. The water was added to alternate furrows at 50 L/min for 12 h. Anhydrous ammonia was applied at rates of 90 kg N/ha to the upper 300 m and 45 kg N/ha for the remainder of the field.

Nine rows were used for each of the dryland treatments and 12 rows for all other treatments, except for the 1979 skip-row variation of the LID-125-mm treatment which consisted of 18 rows. All treatments were established on two adjacent areas, designated S and N. The S and N areas were irrigated on alternate weeks. This was done to enhance the probability of an irrigation either closely preceding or following a rainfall event.

Therefore, even though the same amounts of irrigation water were generally applied to treatments of the S and N areas, the irrigation water sometimes advanced at considerably different rates because of soil water content differences resulting from rainfall.

Soil water contents (gravimetric method) by 30-cm increments to 180-cm depth were obtained at time of seeding and followed harvest to determine soil water depletion values. These values were used in a water balance, along with seasonal rainfall, applied irrigation, and runoff amounts to determine seasonal evapotranspiration. Seasonal rainfall and seasonal evapotranspiration values were calculated from seeding date to harvest date. Deep percolation is negligible on this soil under conventional furrow irrigation practices (Aronovici and Schneider, 1972).

Plots were harvested for grain yield from mid- to late October. The 575-m field was divided into eight segments: 0- to 75-, 75- to 150-, 150- to 225-, 225- to 300-, 300- to 375-, 375- to 450-, 450- to 525-, and 525- to 575-m segments. In 1980 and 1981, four rows the length of each plot segment were combine-harvested and yields reported on a 14% moisture basis. In 1979, three 5 m^2 areas were hand harvested from each segment and the samples threshed and grain yields determined on a 14% moisture basis.

RESULTS AND DISCUSSON

Seasonal rainfall, applied irrigation, runoff, and net seasonal soil water changes for the various treatments are given in Table 1. The long-term average seasonal rainfall at Bushland, Tex., is about 250 mm. Therefore, seasonal rainfall in 1979 was very close to average, while 1980

Table 2. Yield, seasonal evapotranspiration, and water use efficiencies for various water management treatments.

										Water use efficiency							
		Yield				Evapotranspiration (ET)				Seasonal ET				Applied irrigation			
Treatment	Area	1979	1980	1981	Avg.	1979	1980	1981	Avg.	1979	1980	1981	Avg.	1979	1980	1981	Avg.
		Mg/ha				mm				kg grain/m³							
Dryland	S	3.02	1.56	3.54	2.71	366	225	308	300	0.83	0.69	1.14	0.89	--	--	--	--
	N	3.43	1.18	2.45	2.35	360	225	283	289	0.95	0.52	0.86	0.78	--	--	--	--
					2.53				295				0.84				
Dryland, dammed	S	3.16	1.51	2.44	2.37	376	255	305	312	0.84	0.59	0.80	0.74	--	--	--	--
	N	3.41	1.54	2.46	2.47	375	235	303	304	0.91	0.60	0.81	0.77	--	--	--	--
					2.42				308				0.76				
Fully irrigated	S	8.66	6.62	6.35	7.21	653	557	562	591	1.33	1.19	1.13	1.22	0.97	1.03	0.86	0.95
	N	9.30	6.34	6.16	7.27	731	536	675	647	1.27	1.18	0.91	1.12	0.98	0.93	0.76	0.89
					7.24				619				1.17				0.92
LID-250 mm	S	8.13	4.47	4.33	5.64	592	440	510	514	1.37	1.02	0.84	1.08	2.09	1.21	0.79	1.36
	N	7.94	4.83	4.45	5.74	601	448	526	525	1.32	1.08	0.85	1.08	1.83	1.36	0.86	1.35
					5.69				520				1.08				1.36
LID-185 mm (5)	S	7.08	4.15	4.71	5.31	509	418	466	464	1.39	0.99	1.01	1.13	2.19	1.47	1.32	1.66
	N	7.30	3.96	3.58	4.95	548	381	472	467	1.33	1.04	0.76	1.04	2.09	1.36	0.57	1.34
					5.13				466				1.09				1.50
LID-185 mm (3)	S	--	3.97	4.46	--	--	389	485	--	--	1.02	0.92	--	--	1.38	0.93	--
	N	--	4.30	4.47	--	--	403	478	--	--	1.07	0.94	--	--	1.56	0.94	--
LID-125 mm	S	5.67	3.21	5.01	4.63	458	385	384	409	1.24	0.83	1.30	1.12	2.15	1.38	2.22	1.92
	N	5.77	3.42	3.74	4.31	478	348	412	413	1.21	0.98	0.91	1.03	1.89	1.55	0.99	1.48
					4.47				4.11				1.08				1.70
LSD (0.05)					0.71				47				0.20				0.64

was extremely dry all season. The 1981 season was dry until heading, and extremely wet during grain filling. The LID treatments were completely successful in 1979 and 1980 with regards to water management (controlling runoff). There was no loss of either rainfall or irrigation water by runoff. There was some runoff in 1981, but the amounts were fairly low even though the amount of seasonal rainfall was among the highest ever measured during the 42-year history at the Laboratory. The S portion of the study area was first irrigated in 1981 on 29 June, and 75 mm of rainfall occurred during, and within 12 h following the irrigation.

Runoff from the fully irrigated treatment was very appreciable in all years (Table 1). During the three seasons, runoff from individual irrigations ranged from a low of about 20% to more than 50% of the applied water. Typical tailwater runoff values for irrigated fields in the area averaged about 30%. There was also significant amounts of runoff from seasonal rainfall from the fully irrigated treatment. In 1979, a total of 25 mm of the runoff was from rainfall. In 1981, runoff from rainfall was appreciable but could not be partitioned because rainfall occurred during some irrigations. There was no runoff from seasonal rainfall during the very dry summer of 1980.

The lower values for irrigation water applied in 1981, shown in Table 1, resulted because the last scheduled irrigation was deleted due to the unusually large amounts of rainfall late in the season. This large amount of late rainfall also resulted in considerably more soil water being stored in the soil at harvest time than was present at time of seeding.

The yield, evapotranspiration, and water use efficiency values are reported in Table 2. Yield values are the weighed average for the entire length of the field. The yields were much higher, of course, at the upper part of the field where irrigation intake was higher, and much lower at the lower part of the field where very little, if any, irrigation water reached. The yield distributions down the field are shown in Fig. 2 for the LID-185 mm(5) treatment to illustrate the effect.

The water use efficiency values were calculated both on the basis of kg grain/m^3 evapotranspiration (ET) and kg grain/m^3 applied irrigation water (Table 2). When based on ET, the addition of irrigation water increased water use efficiency over dryland and there were very few or no differences between the various irrigation treatments. Grain yield values plotted as a function of seasonal ET for the 3 years are shown in Fig. 3. A very high linear relationship was found, indicating that about 154 kg of grain could be expected for each 10 mm of ET above the threshold value of 143 mm. The linear relationship between grain yield and ET is in agreement with earlier findings. DeWit (1958), Arkley (1963), and Stegman et al. (1980) state that when yields are transpiration-limited, strong linear correlation usually occurs between cumulative seasonal dry matter production and cumulative seasonal transpiration. Furthermore, since transpiration

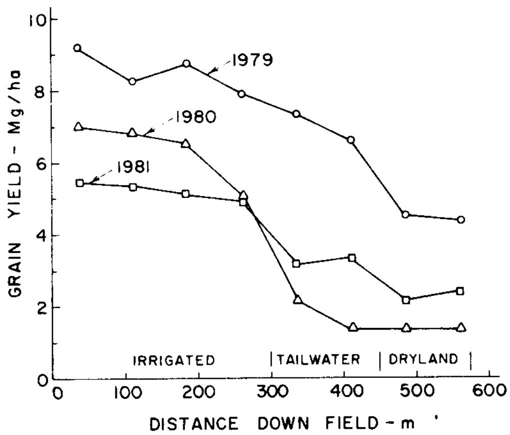

Fig. 2. Grain yield of sorghum at various distances down the field for the LID-185 treatment.

and ET are closely associated, dry matter yield vs. cumulative ET is usually also a linear relationship. In the case of grain crops, a stress related ET threshold for the first grain increment must be met. In the study reported here, the threshold value was about 143 mm. Since a threshold value must be met before any yield of grain is realized, and the yield is generally increased linearly above the threshold value, the highest water use efficiency expressed as kg grain/m^3 ET usually occurs at the highest yield level. This is because the threshold value is a major part of the total ET at low yield levels, but becomes much less significant at high yield levels. This relationship can be seen in Table 2, where the highest water use efficiency values based on ET were for the fully irrigated treatment.

A high water use efficiency, as described above, may not be the most advantageous when irrigation water is limited in relation to land. This is because of increased irrigation water losses as water application frequency and amounts are increased beyond climatic evaporative demand. When irrigation water is added to a field, it can be transpired, evaporated, percolated, lost as runoff, or stored in the soil after harvest. In areas where land is plentiful and irrigation water is limited, emphasis should be given to developing systems that reduce all losses other than transpiration. The water use efficiency values expressed as kg grain/m^3 applied irrigation water, reported in Table 2, demonstrate that the fully irrigated treatment was much less efficient. The primary reason was that considerable amounts of the applied irrigation water were lost as tailwater runoff. Reuse systems can be installed to catch and reapply this water, but design criteria used by the Soil Conservation Service in Texas estimates that one-third of the field runoff is lost. Also, additional pumping energy is required to reapply the water.

The fully irrigated treatment generally also had more water remaining in the soil at harvest, as can be seen in the soil water storage data reported in Table 1. Musick (1970) showed a significant curvilinear relationship between antecedent soil water after harvest and fallow-season storage efficiency of precipitation. Highest storage efficiency values were in the 40 to 50% range when the soil profile was near the wilting point at harvest time, as compared to values as low as 10% when the soil profile was relatively wet at time of harvest. Therefore, the conjunctive use of rainfall and irrigation water can be improved by limiting irrigation, particularly late in the season, to prevent ending the growing season with a relatively wet profile, which minimizes the potential for efficient storage of preseason rainfall for the next crop. Musick and Sletten (1966) also showed that grain sorghum was greatly limited in its ability to use available soil water below 120 cm on Pullman clay loam.

The effectiveness of the LID concept can be seen in Fig. 4. The increase in ET over the dryland treatments is plotted as a function of irrigation water applied. The data shown are from all the irrigation treatments, ranging from 125 mm added irrigation water to 600 mm for some of the fully irrigated treatments. A significant curvilinear, diminishing-return relationship was found showing that as the amount of applied irrigation water was increased, there was a correspondingly lower increase in ET. At the 125- and 185-mm LID treatments, increased ET values were almost equal to amounts of irrigation water added. At the 250-mm level, increased ET values were slightly less than the added irrigation water values. This was because there was generally a little more soil water remaining in the profile at harvest, and there was slightly more runoff than from the lower water level treatments. For the fully irrigated treatment, increases in ET were substantially lower than the irrigation water applied. These findings are in agreement with those of Stewart and Hagan (1973), who demonstrated that crop yields are typically related linearly to seasonal ET and curvilinearly to seasonal irrigation amounts. They also stated that the amount of water not used in ET represented percolation, runoff, and residual extractable water in the soil when the crop was harvested.

The findings illustrated in Fig. 4 have significant implications for water-short areas where significant amounts of rainfall occur. Rainfall is generally sufficient in such areas to satisfy the threshold ET requirement necessary to produce the first increment of grain yield. Consequently, irrigation water added to augment the water supply will increase ET, and therefore, increase grain yield. The relationship depicted in Fig. 3 indicates that for each 10-mm increase in ET, there was a corresponding

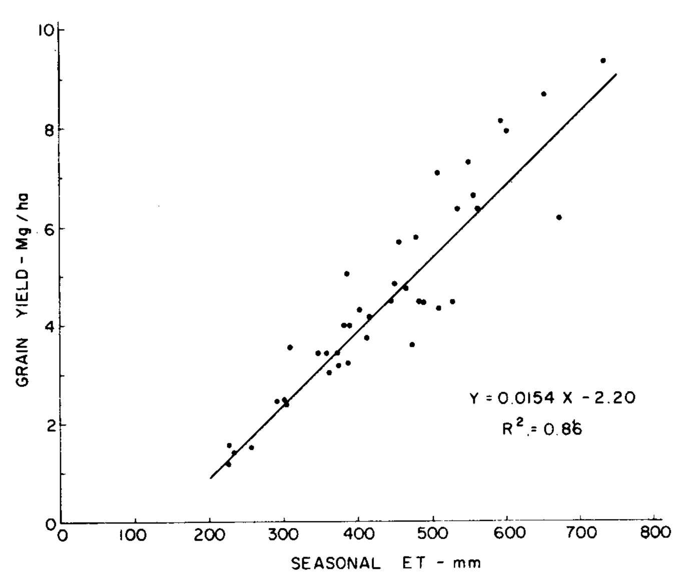

Fig. 3. The relationship between grain yield of sorghum and seasonal evapotranspiration.

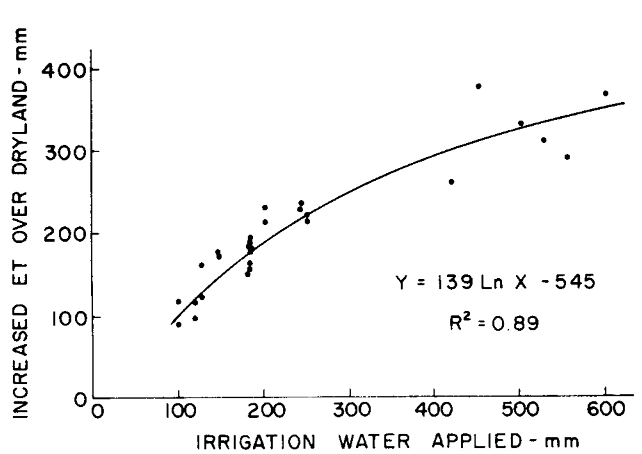

Fig. 4. Increase in evapotranspiration over dryland as a function of the amount of applied irrigation water.

grain yield increase of about 154 kg. The relationship shown in Fig. 4 indicates that with the LID concept, ET was increased in an almost 1:1 ratio with amount of added irrigation water under conditions where deep percolation was negligible. In the High Plains ground water region, the use of good quality water and significant rainfall eliminated the need for leaching fraction for salinity control.

The favorable results of this study are partly attributable to the Pullman clay loam, where percolation of water beneath the root zone is negligible. However, the system should also be efficient on more permeable soils because the length of time that water is applied to a furrow is considerably less than for a conventional furrow irrigation system so there will be less percolation. Only half of the furrows are irrigated in the LID system, management that results in less of the soil surface being wetted. Limiting the percentage of wetted soil surface can reduce evaporation, but Eckern et al. (1967) suggested that net seasonal water savings are likely to be no more than 5%, and will seldom exceed 20% even when only one-fourth to one-third of the surface is wetted and there is incomplete ground cover. However, with short water supplies and high energy costs for pumping irrigation water, a gain of 5% in water use efficiency can be very important.

The 154 kg grain per 10 mm of irrigation water applied in the LID system is much higher, and in many cases, double the value for irrigated grain crops in the Southern High Plains. The adoption of the LID system described here could significantly increase the use efficiency of limited water supplies because the system improves the conjunctive use of limited water with rainfall. Although precipitation is highly variable, the Southern High Plains receives an average of about 500 mm annually, which is sufficient to produce an average of about 1 500 kg/ha of grain sorghum. The addition of only 200 mm irrigation water by the concept described in this study could raise the grain yield to about 5 000 kg/ha. Such systems could sustain irrigation for a longer period in areas of the Southern High Plains where ground water supplies are being depleted.

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